A SIMPLE METHOD OF LOCALIZATION AND VISUALIZATION OF SPONTANEOUS VENOUS PULSATIONS

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Abstract: This paper proposes a simple and undemanding method to highlight or accentuate spontaneous venous pulsations that can be utilized as a feature for both possible future and already present occurrence of glaucoma. The method uses retinal video sequences acquired via fundus video-ophthalmoscope from patients with various degrees of glaucoma progression as well as healthy individuals.

Keywords: Spontaneous venous pulsations, image processing, retinal video sequences

1 ÚVOD

The detection of retinal fundus data in video format as opposed to static image has been relatively new concept. As such it bears all the usual drawbacks of the transition from static form of data to the dynamic. In order to effectively measure information in the temporal domain of dynamic data, a high resolution is required. This in turn results in deficiencies of light in the video sequences, which can be alleviated by giving up on some of the regular features of static retinal images. Such features include high spatial resolution, color information, dynamic contrast and SNR. Another issue would be the fact that a video sequence may be several seconds long, which would hinder possible visual evaluations. Therefore, it is desirable to develop a method for visualizing select features for helping with quick assessment both visually as well as a precursor for future processing.

This paper proposes a simple method for visualizing spontaneous venous pulsations (SVP) present on retina from a video sequence acquired using experimental ophthalmoscope from [2]. The spontaneous venous pulsations (SVP) are a promising feature for simple glaucoma diagnosis and possible preventative glaucoma occurrence indicator. [1]

The outputs produced by this method may be used as a form of quick visual analysis as well as a data map of spontaneous venous pulsations (SVP) occurrences.

2 DATA

The data used are frame-by-frame video sequences of retina centered around optical disc gathered from 74 patients with, among other pathologies, various levels of glaucoma progression.

Data properties are as follows:

- Lossless MJPEG encoding
- Resolution and framerate: 1000×770 px, 25 fps
- Color coding: 8-bit grayscale
- Duration: 10.16 sec

- FOV: 20°×15°

2.1 PREPROCESSING

Image registration algorithm described in [2] was used to eliminate fast, spontaneous eye movements and to center the image on the optical disc. To remove remaining saccadic movements a temporal median filter was used; median filter of window size 9 – a balance between filtering effectiveness and half of the value of heart rate frequency in corresponding frames. Next, to eliminate general noise a spatial weighted-mean form of low-pass filter was used.

A frame of preprocessed sequence is shown in Fig. 1:

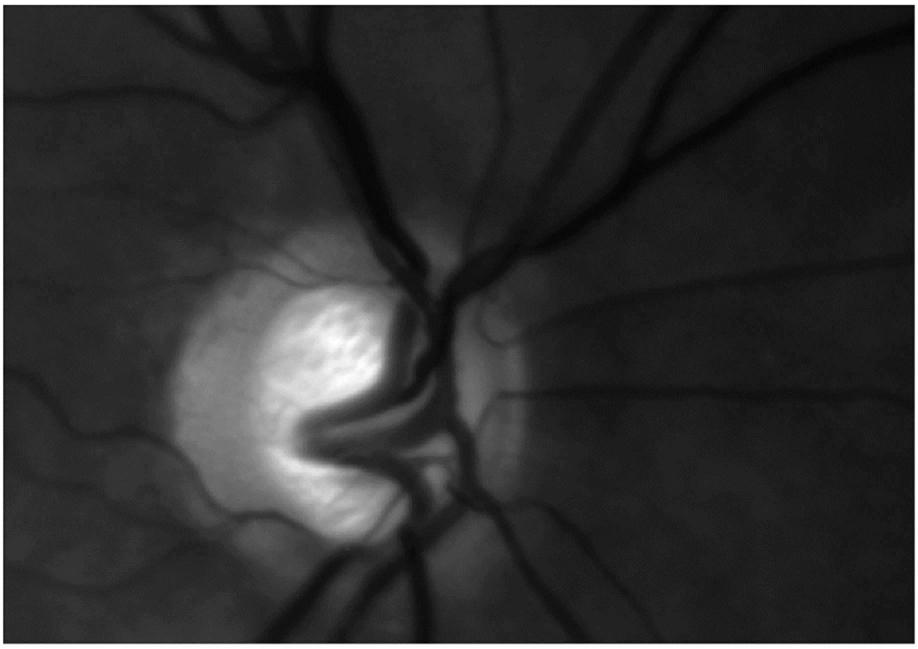

Figure 1: An image of a frame of input data

3 METHODS

The method is based upon detection of temporal and spatial changes of brightness in the video sequences. Therefore, it is very desirable to eliminate all forms and sources of movement and changes in the sequence that do not correspond to the spontaneous venous pulsations. One of the ways would be to remove all temporal frequencies that are not involved in forming the SVPs. Thus, a zero-ing of non-heart rate physiological frequencies in the temporal spectrum of the video sequence is performed. This method proved to be fast and effective way of removing much of the useless movement and brightness changes.

The movement and brightness difference detection is performed via 3D convolution of the whole sequence stack with a specifically designed form of 3D Sobel mask. The mask is a result of convolution of three 1D short signals for filtering and differentiating; obtained as follows: A 1D Gaussian curve of length 9 is generated to serve as a form of low pass filter. Next, a longer 1D Gaussian curve is produced, its middle value zero-ed and its second half inverted. The equation 1 shows this process:

$$M_t = h_t * (h_x * {h_x}^T) \qquad (1)$$

where M_t denotes resulting 3D mask, natively oriented in the time direction, h_x corresponds to a 1D Gaussian, h_t corresponds to 1D difference curve, which is oriented (transposed) into third dimension.

Resulting mask is illustrated in Fig. 2 and 3:

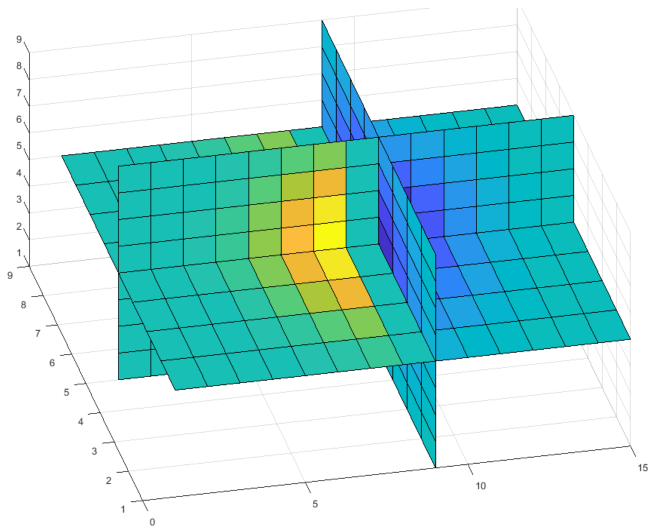

Figure 2: Visualization of the difference mask

0,00	0,01	0,01	0,02	0,02	0,02	0,01	0,01	0,00
0,02	0,04	0,07	0,11	0,12	0,11	0,07	0,04	0,02
0,06	0,15	0,29	0,42	0,47	0,42	0,29	0,15	0,06
0,20	0,47	0,88	1,28	1,45	1,28	0,88	0,47	0,20
0,47	1,13	2,12	3,08	3,49	3,08	2,12	1,13	0,47
0,88	2,12	3,95	5,75	6,51	5,75	3,95	2,12	0,88
1,28	3,08	5,75	8,37	9,48	8,37	5,75	3,08	1,28
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
-1,28	-3,08	-5,75	-8,37	-9,48	-8,37	-5,75	-3,08	-1,28
-0,88	-2,12	-3,95	-5,75	-6,51	-5,75	-3,95	-2,12	-0,88
-0,47	-1,13	-2,12	-3,08	-3,49	-3,08	-2,12	-1,13	-0,47
-0,20	-0,47	-0,88	-1,28	-1,45	-1,28	-0,88	-0,47	-0,20
-0,06	-0,15	-0,29	-0,42	-0,47	-0,42	-0,29	-0,15	-0,06
-0,02	-0,04	-0,07	-0,11	-0,12	-0,11	-0,07	-0,04	-0,02
0,00	-0,01	-0,01	-0,02	-0,02	-0,02	-0,01	-0,01	0,00

Figure 3: A single slice through the difference mask

This mask is used as a Sobel mask, separately oriented in each of the three dimension and convolved with the input video sequence.

$$D_t = M_t * V; \quad D_x = (M)^T_{t\to x} * V; \quad D_y = (M)^T_{t\to y} * V \tag{2}$$

Where D_t, D_x, D_y denotes resulting difference matrix in the time, x-spatial, y-spatial domain respectively, M_t denotes difference mask oriented in time direction, V denotes the input video sequence, $(M)^T_{t\to x}$ implies transposition from time orientation to x orientation (vertical)

The border effects of the convolutions are corrected by repeating the border pixel values and disposing of the processed values beyond borders after the convolution.

The process produces three distinct video matrices, each indicate a measure of changes for each pixel and to lesser extent in its neighborhood for each of the three dimensions of the video sequence. Since the differential character of the Sobel-like mask produces anisotropic data, each of the resulting difference matrixes are subjected to pixel-by-pixel absolute value operator.

Non-directional spatial difference matrix is obtained using Euclidean metric:

$$D_p = \sqrt{{D_x}^2 + {D_y}^2} \tag{3}$$

4 RESULTS

The results of this process are spatial and temporal 3D matrices of difference of brightness formed as a video whose pixels containing high values correspond to the regions where brightness changes in the original video sequence occur. Since we have spatial and temporal brightness changes contained in different matrices, we can use this information separately.

The form and format of this publication disallows us to show the resulting matrices in form of video and thus, the results are shown as slices of the matrices as images.

An example of the video can be seen in [Difference matrix on G-drive](#).

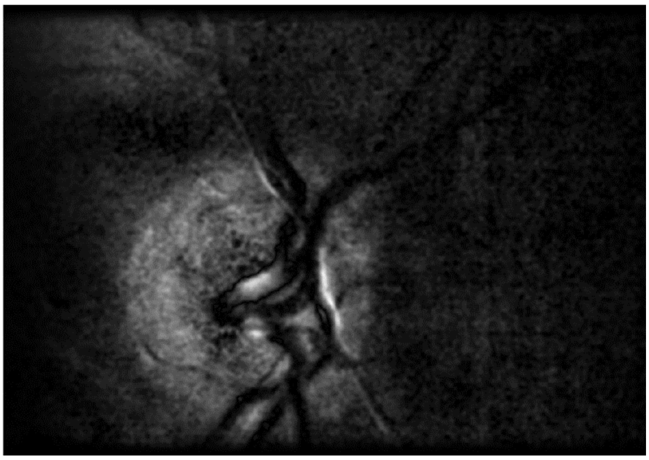

Figure 4: A slice of temporal matrix in time of a pulse

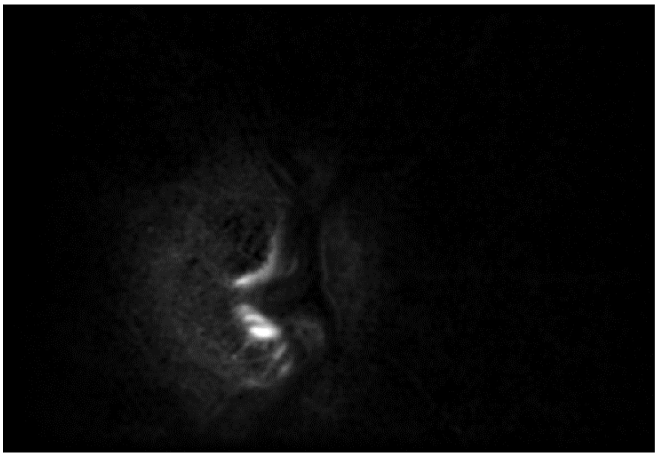

Figure 5: A slice of temporal matrix in time between pulses

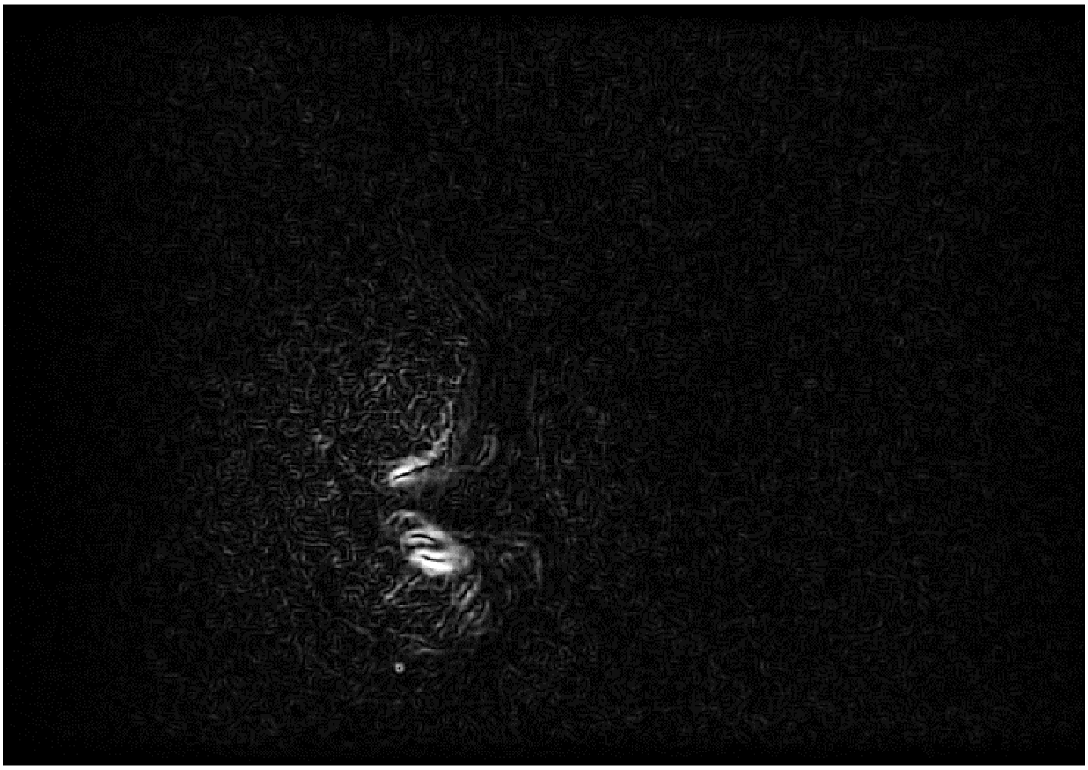

Figure 6: A slice of spatial matrix

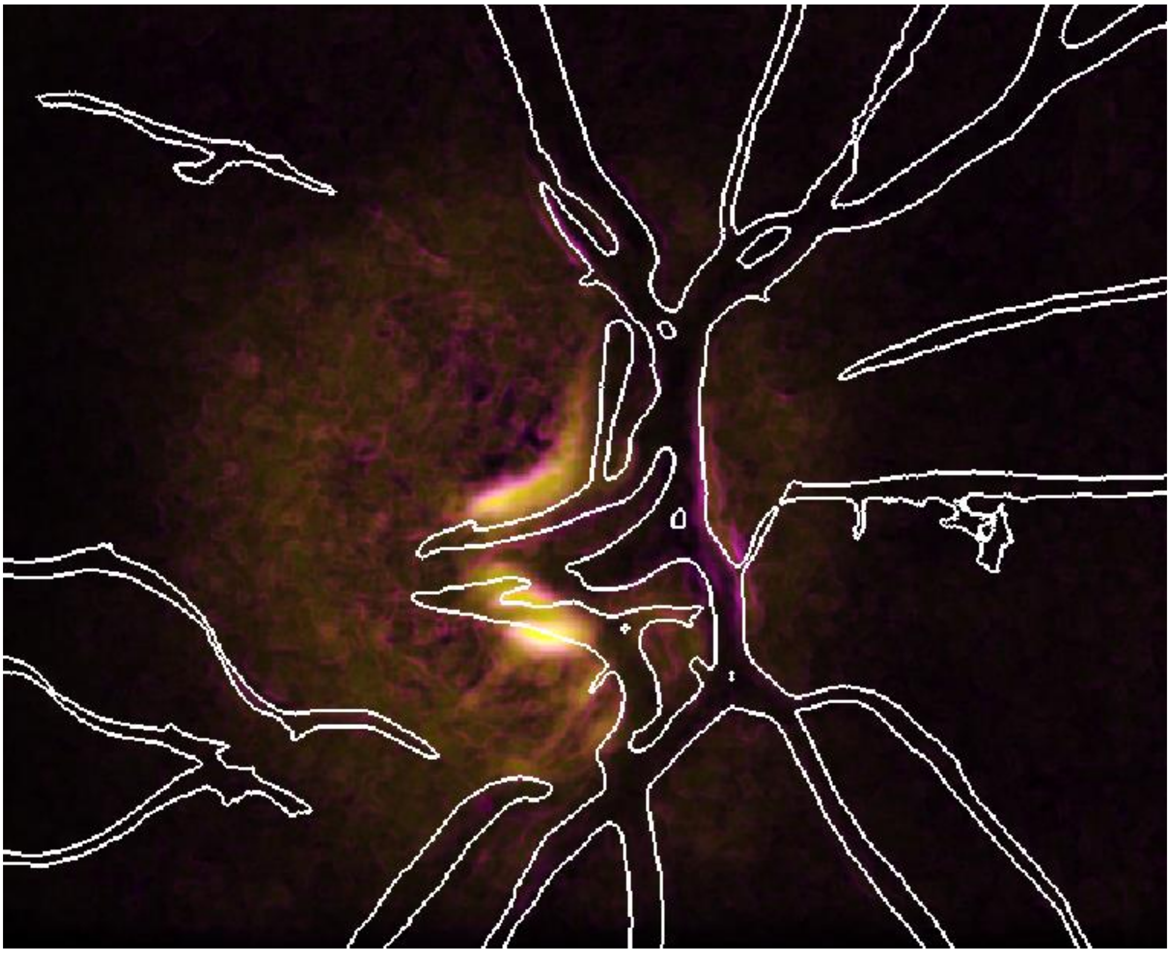

Figure 7: Pseudocolored combination of slices from spatial and temporal matrices, with vessel outlines (detected using [3]) shows movement occurring on the edges of some vessels. Temporal matrix is illustrated in shades of yellow and spatial in shades of magenta.

5 CONCLUSION

A quick, computationally undemanding method for evaluating and visualizing movements and brightness changes was proposed in this paper. The images from resulting video sequences are shown above. In the images, a high response can be found especially on boundaries of some vessels. This is the direct result of the vessels' movement. As was stated before, the form of this paper prevents showing the true results, which are in form of videos. The resulting images may be, besides visualizations, also used as a maps of activities for further processing.

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